CROP PROFILE FOR BRASSICA VEGETABLES IN CANADA, 2015

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Preface

National crop profiles are developed under the Pesticide Risk Reduction Program (PRRP), a program of Agriculture and Agri-Food Canada (AAFC). The national crop profiles provide baseline information on crop production and pest management practices and document the pest management needs and issues faced by growers. This information is developed through extensive consultation with stakeholders.

Information on pest management practices and pesticides is provided for information purposes only. No endorsement of any pesticide or pest control technique, discussed, is implied. Product names may be included and are meant as an aid for the reader, to facilitate the identification of pesticides in general use. The use of product names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

For detailed information on growing brassica vegetable crops, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

Every effort has been made to ensure that the information in this publication is complete and accurate. Agriculture and Agri-Food Canada does not assume liability for errors, omissions, or representations, expressed or implied, contained in any written or oral communication associated with this publication. Errors brought to the attention of the authors will be corrected in subsequent updates.

Agriculture and Agri-Food Canada gratefully acknowledges the contributions of provincial crop specialists, industry specialists and growers in the gathering of information for this publication.

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Contents

Crop Production 2
Industry Overview 2
Production Regions 2
North American major and minor field trial regions 4
Cultural Practices 6
Abiotic Factors Limiting Production 9
Nutritional Balance 9
Head Splitting of Cabbage 9
Oedema 9
Diseases 10
Key issues 10
Black rot (*Xanthomonas campestris* pv. *campestris*) 20
Blackleg (*Phoma lingam*) 21
Clubroot (*Plasmodiophora brassicae*) 21
Damping-off (*Pythium* spp., *Fusarium* spp., and *Rhizoctonia* spp.) 22
Rhizoctonia diseases (wirestem, root rot, bottom rot, and head rot) (*Rhizoctonia solani*) 23
Bacterial (peppery) leaf spot (*Pseudomonas syringae* pv. *maculicola*) 24
Grey leaf spot (*Alternaria brassicae*) and black leaf spot (*A. brassicola*) 25
Downy mildew (*Hyaloperonospora parasitica*) 26
Fusarium wilt (yellows) (*Fusarium oxysporum* f.sp. *conglutinans*) 27
Head rot (*Pectobacterium* spp. and *Pseudomonas* spp.) 27
Sclerotinia rot (*Sclerotinia sclerotiorum*) 28
Grey mould (*Botrytis cinerea*) 29
Insects and Mites 30
Key issues 30
Aphids: Cabbage aphid (*Brevicoryne brassicae*) and green peach aphid (*Myzus persicae*) 42
Leafminer (*Liriomyza* spp.) 42
Caterpillars: Imported cabbageworm (*Pieris rapae*), diamondback moth (*Plutella xylostella*) and cabbage looper (*Trichoplusia ni*) 43
Cutworm (family Noctuidae) 44
Cabbage maggot (*Delia radicum, Delia* spp.) 45
Flea beetles (*Phyllotreta spp.*): Crucifer flea beetle (*P. cruciferae*) 46
Swede midge (*Contarinia nasturtii*) 47
Thrips (*Thrips tabaci*) 48
Tarnished plant bug (*Lygus lineolaris*) 49
Slugs (Various species) 49
Weeds 51
Key Issues 51
Annual and perennial weeds 58
Resources 59
Integrated pest management / integrated crop management resources for production of brassica crops in Canada 59
Provincial Crop Specialists and Provincial Minor Use Coordinators 60
National and Provincial Vegetable Grower Organizations 61
Appendix 1 62
References 63

List of Tables and Figure

Table 1. General information on the production of brassica vegetables in Canada (2015) 2
Table 2. Distribution of brassica vegetable production in Canada (2015) 3
Table 3. Brassica vegetable production and pest management schedule in Canada 8
Table 4. Occurrence of diseases in broccoli and cabbage crops in Canada 11
Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada 12
Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada 14
Table 7. Occurrence of insect pests in broccoli and cabbage crops in Canada 31
Table 8. Adoption of insect management practices for broccoli and cabbage production in Canada 32
Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada 34
Table 10. Occurrence of weeds in broccoli and cabbage crops in Canada 52
Table 11. Adoption of weed management practices for broccoli and cabbage production in Canada 53
Table 12. Herbicides and bioherbicides registered for the control of weeds in brassica vegetable production in Canada 55

Figure 1. Common zone map: North American major and minor field trial regions 5

Crop Profile for Brassica Vegetables in Canada

The Brassica vegetables, also known as cruciferous vegetables or cole crops, belong to the Brassicaceae, commonly known as the cabbage or mustard family. This diverse family includes numerous important agricultural and horticultural crops, as well as many weeds. This crop profile covers the brassica vegetables, cabbage, broccoli, cauliflower and Brussels sprouts with detailed information on cabbage and broccoli. These vegetables are cultivars of one plant, *Brassica oleracea* as listed below:

Broccoli (*B. oleracea* var. *italica*)

Brussels sprouts (*B. oleracea* var. *gemmifera*)

Cabbage (*B. oleracea* var. *capitata)*

Cauliflower (*B. oleracea* var. *botrytis*)

B. oleracea is native to coastal areas of Europe and the Mediterranean region and has been used for food for over 2,500 years. Through cultivation and selection, the different cultivars were developed. Although *B. oleracea* has been used since Roman times, references to the main cultivars became more common in the literature from about the 1600's. The brassica crops were brought to North America by European settlers.

Brassica vegetables are important fresh and processing crops. Cabbage is grown for the fresh market and is processed into sauerkraut, egg rolls and coleslaw. It also has potential for other specialty markets for the various types including red and savoy. Broccoli is grown for three main markets in Canada: fresh, frozen and organic, with the majority going to the fresh market. There are two main types of broccoli, the most common being sprouting/Italian broccoli (*Brassica oleracea* var. *italica*) and the other heading broccoli (*Brassica oleracea*). Cauliflower is consumed fresh or cooked. There are numerous varieties with curds that differ in colour including white, orange, green and purple. Brussels sprouts are enlarged buds that grow along the stalk and are consumed as fresh or cooked vegetables.

Brassica vegetables are very nutritious and are high in vitamins A, C and K. They are a good source of minerals including potassium, manganese, iron and magnesium. They are also high in folic acid, soluble fibre and antioxidants which protect against cancer and heart disease.

Crop Production

Industry Overview

Table 1. General information on the production of brassica vegetables in Canada (2015)

Crops	Broccoli	Cauliflower	Brussels sprouts	Regular Cabbage
Canadian Production (2015)[1]	40,898 metric tonnes	30,597 metric tonnes	5,991 metric tonnes	141,069 metric tonnes
	4,149 hectares	1,718 hectares	585 hectares	4,150 hectares
Farm gate value (2015)[1]	$61 million	$30 million	$9 million	$58 million
Food available in Canada (fresh) (2015)[2]	2.70 kg/ person	0.23 kg/ person	2.23 kg/ person	3.90 kg/ person
Exports (fresh) (2015)[2]	14,070 metric tonnes		857 metric tonnes	86,122 metric tonnes
	$16 million		$2 million	$86 million
Imports (fresh) (2015)[2]	156,899 metric tonnes		N/A	156,758 metric tonnes
	$274 million		$23 million	$196 million

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database) (accessed: 2018-03-26).

[2]Agriculture and Agri-Food Canada. Statistical Overview of the Canadian Vegetable Industry, 2015. AAFC No. 12162E-PDF (October 2016).

Production Regions

Brassica vegetables are biennial plants, but are generally grown as annuals. They are suited to the climate of many regions across Canada.

Cabbage is grown commercially in most provinces in Canada. The majority of production takes place in Quebec (45%) and Ontario (35%), with minor production in British Columbia (6%) (Table 2).

Broccoli can be grown in all provinces, but commercial production is concentrated in only a few. Ontario (42%) and Quebec (39%) are the largest producers, with British Columbia (7%) also producing significant amounts commercially (Table 2).

Production of cauliflower is concentrated in Quebec (46%) and Ontario (28%) (Table 2).

Ontario and British Columbia are the main provinces of production for Brussels sprouts, having 44% and 35% of the total Canadian acreage, respectively. Significant production also occurs in Quebec (17%) (Table 2).

Table 2. Distribution of brassica vegetable production in Canada (2015)[1]

Production Regions	Broccoli	Cauliflower	Brussels sprouts	Regular cabbage
	Planted Area 2015 (hectares) (percent national production)	Planted Area 2015 (hectares) (percent national production)	Planted Area 2015 (hectares) (percent national production)	Planted Area 2015 (hectares) (percent national production)
British Columbia	285E[4] (7%)	89E[4] (1%)	202 (35%)	252 (6%)
Alberta	F[2]	F[2]	X[3]	X[3]
Saskatchewan	8 (< 1%)	X[3]	0	37 (1%)
Manitoba	X[3]	X[3]	0	X[3]
Ontario	1,745 (42%)	486 (28%)	256E[4] (44%)	1,460 (35%)
Quebec	1,622 (39%)	794 (46%)	99 (17%)	1,847 (45%)
New Brunswick	21 (1%)	6	X[3]	49 (1%)
Nova Scotia	X[3]	X[3]	12	122 (3%)
Prince Edward Island	F[2]	X[3]	X[3]	78 (2%)
Newfoundland and Labrador	F[2]	5E (<1%)	X[3]	54 (1%)
Canada	4,149 (100%)	1,718 (100%)	585 (100%)	4,150 (100%)

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database) (accessed: 2018-03-26).

[2]F - Too unreliable to be published.

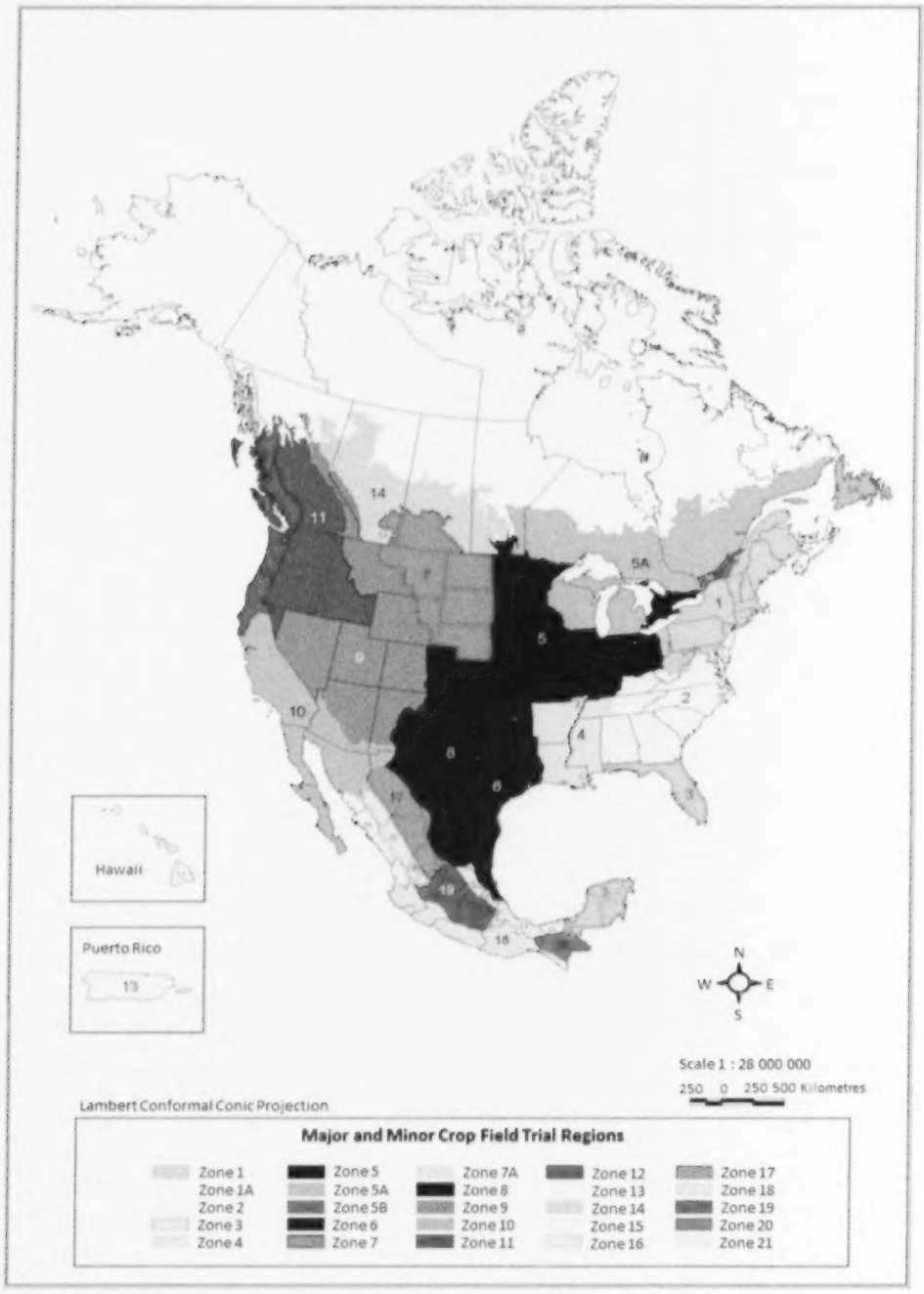
[3]X - Suppressed to meet the confidentiality requirements of the Statistics Act.

[4]E - Use with caution.

North American major and minor field trial regions

Major and minor crop field trial regions (see Figure1) are used by the Pest Management Regulatory Agency (PMRA) in Canada and the United States (US) Environmental Protection Agency (EPA), to identify the regions where residue chemistry crop field trials are required to support the registration of new pesticide uses. The regions are based on a number of parameters, including soil type and climate but they do not correspond to plant hardiness zones. For additional information on field trial regions and requirements, consult the PMRA Regulatory Directive 2010-05 "*Revisions to the Residue Chemistry Crop Field Trial Requirements*" (www.hc-sc.gc.ca/cps-spc/pubs/pest/_pol-guide/dir2010-05/index-eng.php).

Figure 1. Common zone map: North American major and minor field trial regions[1]



[1]Produced by: Spatial Analysis and Geomatics Applications, Agriculture Division, Statistics Canada, February 2001.

Cultural Practices

Cabbage and broccoli grow best in well-drained clay and clay loam soils, but also do well in sandy loam and loam soils. Well drained sandy loam soils are best suited for early varieties, while loamy and clay loam soils are best suited for late varieties. Late season varieties are somewhat more tolerant of poor drainage. A soil pH of 6.0 to 6.8 gives optimal yields. Maintaining soil pH close to neutral helps prevent diseases such as clubroot that thrive in acidic soils. Lime is applied six weeks prior to planting if the pH in mineral soils is below 6.2. A rotation of between two to five years out of the brassicaceae crop family is best to reduce the carry-over of insects and diseases to new crops.

Adequate soil nutrient levels are necessary to ensure optimum growth. A soil nutrient test, performed in the fall or spring, several weeks before seedbed preparation begins will help determine fertilizer requirements. Nutrients are applied on a field-by-field basis, depending on the results of the soil test and the requirements of the specific variety being grown. Fertilizers are broadcast and disked into the soil before seeding or transplanting. Boron, magnesium and molybdenum may be needed on sandy soils with low organic matter or when pH is lower than 5.5 in soils that cannot be limed due to rotational considerations. Broccoli and cabbage tend to require a large amount of nitrogen at planting with the remainder side dressed at three weeks after planting.

Seedlings for early season crops are first established in greenhouses. For later plantings, seedlings can be established in cold frames. Direct seeding for late summer and early fall crops can be done in well drained soils. Fungicide seed treatments help prevent seed-borne diseases. In the greenhouse, seeds may be sown directly into plug-trays.

Seedlings are transplanted into the field at four to six weeks when they are about 15 cm high and have six to eight true leaves. Before transplanting, the seedlings are "hardened off" by decreasing water and temperature and increasing ventilation. Seeding to harvest takes 12 to13 weeks altogether. Broccoli and cabbage are produced for early, mid and late season harvest. Growers plant in successive stages so that from the earliest harvest to the end of the season there is continual production. Often growers have contracts for supply with grocery store chains and thus must have a constant supply ready for shipment. The use of plastics placed over the soil can allow cabbage transplants to reach maturity as early as late June.

Broccoli and cabbage are considered to be cool season crops and are cold tolerant, but cabbage is more cold tolerant than broccoli. Young cabbage plants are able to withstand temperatures of -10°C for short periods of time. Growth, however, is arrested below 0°C and above 25°C, and is highest between 15 and 20°C. The plants require a regular water supply of 25 mm per week during the growing season, with water shortages being detrimental to head development. Seeds germinate at temperatures as low as 5°C, with optimum germination at 27°C. High summer temperatures delay maturity and increase vegetative growth, while cool temperatures hasten maturity and may induce bolting.

The harvest season for broccoli begins in June and ends in October, with the harvest season for cabbage being from June until November. Broccoli and cabbage are generally hand harvested. A mechanical harvesting aid that transports cartons to and from the workers using a series of conveyor belts may be used. Broccoli is washed in the box, cooled and slush ice pumped into the boxes to remove the field heat as quickly as possible to maintain firm heads.

Broccoli cannot be stored for very long, therefore, is shipped directly to retail outlets or a wholesale location. Cabbage destined for storage is harvested during the months of October and November. Heads showing signs of insect, freezing, sunscald or bruising damage are discarded or sent directly to market. Cultivars vary in their ability to be stored, with dense-headed, slowly maturing cultivars being able to be stored for longer periods of time. Long term (five to six months) storage of cabbage is possible and allows continuous supply until the following March.

Table 3. Brassica vegetable production and pest management schedule in Canada

Time of Year	Activity	Action
November - February	-	No action
March	Plant care	Early variety transplant seed germination
	Weed management	Burn down of weeds (weather dependent)
April	Plant care	Hardening-off of early variety transplants
	Soil care	First pass with discs if necessary
	Weed management	Burn down of perennials (weather dependent)
May	Plant care	Transplanting begins in successive stages form early to late varieties
	Soil care	Broadcast fertilizer applications
	Disease management	Fungicide applications begin on first plantings
	Insect and mite management	Occasional sprays for some early season or sporadic pests
	Weed management	Possible application of post emergence herbicides
June	Plant care	Transplanting continues and possibly irrigation (weather dependent)
	Soil care	Side dressing beginning with earliest plantings
	Disease management	Monitoring for disease; preventative spray programs maintained for certain diseases
	Insect and mite management	Monitoring for pests; protective spray programs maintained for certain pests
	Weed management	Continued post emergence herbicide applications for late flush
July	Plant care	Irrigation and supplemental foliar feeding based on tissue sampling results
	Disease management	Monitoring for disease; preventative spray programs maintained for certain diseases
	Insect and mite management	Monitoring for pests; protective spray programs maintained for certain pests
	Weed management	Scuffling between rows to break up newly emerging weeds
August	Plant care	Irrigation and supplemental foliar feeding continued based on tissue sampling results
	Soil care	Scuffling between rows to improve moisture penetration
	Disease management	Monitoring for disease; preventative spray programs maintained for certain diseases
	Insect and mite management	Monitoring for pests; protective spray programs maintained for certain pests
September	Plant care	Early varieties may be harvested, irrigation continued
	Disease management	Monitoring for disease; preventative spray programs maintained for certain diseases
	Insect and mite management	Monitoring for pests; protective spray programs maintained for certain pests
October	Plant care	Harvest of later varieties continues until the end of the month
	Soil care	Disc or plough under crop debris

Abiotic Factors Limiting Production

Nutritional Balance

Typical disorders caused by nutrient imbalances include tip burn (calcium deficiency), hollow stem and watery core (boron deficiency), interveinal chlorosis on leaves (magnesium deficiency), narrow, deformed leaves known as "whip tail" (molybdenum deficiency) and sulphur deficiency.

Head Splitting of Cabbage

Head splitting is mainly a problem with early season cabbage. The disorder occurs when stress due to insufficient moisture is followed by heavy rain. The quick growth associated with the sudden moisture input, high temperatures and high fertility can cause the head to split. Proper irrigation can help prevent splitting and varieties can be chosen that are less susceptible to the problem. Deep cultivation to break some of the plant roots can also help prevent the disorder.

Oedema

Oedema usually occurs in the fall, when cabbage is left in the field following wet weather or over-irrigation. With high relative humidity and cool air temperatures, transpiration rates may be reduced despite continued water absorption by the roots. Cells become congested as a result and may rupture, resulting in the raised, rough lesions on the lower leaf surfaces known as oedema. To make the head marketable, several outer leaves may need to be removed.

Diseases

Key issues

- The development of resistant varieties and new approaches to the management of a number of diseases of brassica crops is required.
- There is a need for improved understanding of black rot and the development of preventative measures for control of this disease including resistant cultivars and seed treatments.
- There is a need for the registration of new products for the control of many brassica diseases.

Table 4. Occurrence of diseases in broccoli and cabbage crops in Canada[1,2]

Disease	Cabbage			Broccoli	
	British Columbia	Ontario	Quebec	Ontario	Quebec
Damping -off					
Blackleg					
Rhizoctonia diseases					
Clubroot					
Grey leafspot and black leafspot					
Cladosporium leafspot					
Bacterial leaf spot (peppery leaf spot)					
Downy mildew					
Fusarium wilt (yellows)					
Black rot					
Head rot					
Sclerotinia rot (white mould)					
Gray mould					

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest not present.

Data not reported.

[1]Source: Brassica crop stakeholders in reporting provinces. The data reflect the 2015, 2014 and 2013 production years.

[2]Refer to Appendix 1 for further information on colour coding of occurrence data.

Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada[1]

	Practice / Disease	Black rot (*Xanthomonas* sp.)	Grey leafspot and black leafspot	Rhizoctonia diseases	Fusarium yellows	Clubroot
Avoidance	Resistant varieties					
	Planting/ harvest date adjustment					
	Crop rotation					
	Choice of planting site					
	Optimizing fertilization					
	Reducing mechanical damage or insect damage					
	Thinning/ pruning					
	Use of disease-free seed, transplants					
Prevention	Equipment sanitation					
	Mowing/ mulching/ flaming					
	Modification of plant density (row or plant spacing; seeding rate)					
	Seeding/ planting depth					
	Water/ irrigation management					
	End of season crop residue removal/ management					
	Pruning out/ removal of infected material throughout the growing season					
	Tillage / cultivation					
	Removal of other hosts (weeds/ volunteers/ wild plants)					
Monitoring	Scouting/ trapping					
	Records to track diseases					
	Soil analysis					
	Weather monitoring for disease forecasting					
	Use of portable electronic devices in the field to access pest identification /management information					
	Use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					

...continued

Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada[1] (continued)

Practice / Disease		Black rot (*Xanthomonas* sp.)	Grey leafspot and black leafspot	Rhizoctonia diseases	Fusarium yellows	Clubroot
Decision making tools	Economic threshold					
	Weather / weather-based forecast / predictive model					
	Recommendation from crop specialist					
	First appearance of pest or pest life stage					
	Observed crop damage					
	Crop stage					
Suppression	Pesticide rotation for resistance management					
	Soil amendments					
	Biopesticides					
	Controlled atmosphere storage					
	Targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					
Crop specific practices	Spore trapping to monitor for disease					

This practice is used to manage this pest by at least some growers.

This practice is not used by growers to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]Source: Brassica vegetable (cabbage and broccoli) stakeholders in reporting provinces (Ontario and Quebec). The data reflect the 2015, 2014 and 2013 production years.

Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada

Active Ingredient[1]	Specific Crop or Crop Group (CG) of Registration[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Seed treatment							
azoxystrobin	CG5: Brassica (cole) leafy vegetables	methoxy-acrylate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	seed rot / pre-emergence damping-off (*Rhizoctonia solani*)
captan (for use by comercials seed treaters only)	broccoli, Brussels sprouts, cabbage, cauliflower	phthalimide	multi-site contact activity	multi-site contact activity	M4	RE	seed decay, damping-off, seedling blight
fludioxonil (seed treatment for use by commercial seed treaters only)	CG5: Brassica (cole) leafy vegetables	phenylpyrrole	E2: signal transduction	MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1)	12	RE	seed decay, damping-off, seedling blights (*Fusarium* spp., *Rhizoctonia* spp.)
metalaxyl seed treatment (for importation of treated seed only)	broccoli, Brussels sprouts, cabbage, cauliflower	acylalanine	A1: nucleic acids synthesis	RNA polymerase I	4	R	pythium damping-off
metalaxyl-M and S-isomer	Crop Subgroup 5A: Head and stem brassica	acylalanine	A1: nucleic acids synthesis	RNA polymerase I	4	R	pythium damping-off
thiram	broccoli, Brussels sprouts, cabbage, cauliflower	dithiocarbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	seed decay, seedling blight, damping-off
Trichoderma harzanium Rifai strain KRL-AG2	greenhouse vegetable transplants	biological	unknown	unknown	N/A	RE	root rot (*Pythium* spp., *Rhizoctonia* spp., *Fusarium* spp.) (suppression)

...continued

Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG) of Registration[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Application to planting mixes and soil							
Bacillus subtilis strain MBI600 (growing medium with biofungicide)	greenhouse vegetable transplants	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	damping off and root diseases (*Pythium* spp.) (suppression)
Bacillus subtilis strain QST 713	CG5: Brassica (cole) leafy vegetables	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	rhizoctonia damping-off and root rot, phytophthora root rot, pythium root rot
Trichoderma harzanium Rifai strain KRL-AG2	greenhouse vegetable transplants	biological	unknown	unknown	N/A	RE	root rot (*Pythium* spp., *Rhizoctonia* spp., *Fusarium* spp.) (suppression)
captan	broccoli, Brussels sprouts, cabbage, cauliflower, kale	phthalimide	multi-site contact activity	multi-site contact activity	M4	RE	damping-off, root rot
Coniothyrium minitans strain CON/M/91-08	cabbage	not classified	unknown	unknown	N/A	R	*Sclerotinia sclerotiorum* (suppression / control)
Foliar treatment							
Bacillus subtilis strain QST 713	CG5: Brassica (cole) leafy vegetables	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	sclerotinia rot, downy mildew, pin rot (alternaria / xanthomonas complex), powdery mildew
Trichoderma harzanium Rifai strain KRL-AG2	greenhouse vegetable transplants	biological	unknown	unknown	N/A	RE	*Botrytis cinerea* (suppression)

...continued

Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG) of Registration[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
ametoctradin + dimethomorph	CG5: Brassica (cole) leafy vegetables	triazolo-pyrimidylamine + cinnamic acid amide	C8: respiration + H5: cell wall biosynthesis	complex III: cytochrome bc1 (ubiquinone reductase) at Qo site, stigmatellin binding sub-site + cellulose synthase	45 + 40	R + RE	downy mildew
azoxystrobin	cabbage	methoxy-acrylate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	alternaria leaf spot (*Alternaria brassicae*)
azoxystrobin + difenoconazole	CG5: Brassica (cole) leafy vegetables	methoxy-acrylate + triazole	C3: respiration + G1: sterol biosynthesis in membranes	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + c14-demethylase in sterol biosynthesis (erg11/cyp51)	11 + 3	R + RE	alternaria blight, powdery mildew
boscalid + pyraclostrobin	Crop Subgroup 5A: Head and stem brassica	pyridine-carboxamide + methoxy-carbamate	C2: respiration + C3: respiration	complex II: succinate-dehydrogenase + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	7 + 11	R + R	botrytis grey mould, downy mildew (suppression)
chlorothalonil	broccoli, Brussels sprouts, cabbage, cauliflower	chloronitrile (phthalonitrile)	multi-site contact activity	multi-site contact activity	M5	RE	alternaria leaf spot, downy mildew

...continued

Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG) of Registration[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
chlorothalonil + difenoconazole	broccoli, Brussels sprouts, cabbage, cauliflower	chloronitrile (phthalonitrile) + triazole	multi-site contact activity + G1: sterol bioslynthesis in membranes	multi-site contact activity + C14-demethylase in sterol biosynthesis (erg11/cyp51)	M5 + 3	RE + RE	alternaria leaf spot, downy mildew
copper (present as basic copper sulfate)	broccoli, cabbage, cauliflower	inorganic	multi-site contact activity	multi-site contact activity	M1	R	downy mildew, black leaf spot, grey leaf spot
copper (present as basic copper sulfate)	Brussels sprouts	inorganic	multi-site contact activity	multi-site contact activity	M1	R	bacterial leaf spot, downy mildew, black leaf spot , grey leaf spot
copper (present as copper octanoate)	CG5: Brassica (cole) leafy vegetables	inorganic	multi-site contact activity	multi-site contact activity	M1	R	black rot (*Xanthomonas campestris* pv. *campestris* (suppression)
cyazofamid	brassica transplants	cyano-imidazole	C4: respiration	complex III: cytochrome bc1 (ubiquinone reductase) at Qi site	21	R	pythium damping-off and root rot
cyazofamid	CG5: Brassica (cole) leafy vegetables	cyano-imidazole	C4: respiration	complex III: cytochrome bc1 (ubiquinone reductase) at Qi site	21	R	downy mildew (suppression)
cyprodinil + fludioxonil	cabbage	anilino-pyrimidine + phenylpyrrole	D1: amino acids and protein synthesis + E2: signal transduction	methionine biosynthesis (proposed) (cgs gene) + MAP/histidine-kinase in osmotic signal transduction (os-2, HoG1)	9 + 12	RE + RE	alternaria leaf blight (suppression)
difenoconazole	Crop Subgroup 5A: Head and stem brassica	triazole	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	RE	alternaria blight, powdery mildew

...continued

Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG) of Registration[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
fenamidone	CG5: Brassica (cole) leafy vegetables	imidazolinone	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	downy mildew (suppression)
fluazinam	CG5: Brassica (cole) leafy vegetables	2,6-dinitro-aniline	C5: respiration	uncouplers of oxidative phosphorylation	29	R	clubroot
fluopicolide	CG5: Brassica (cole) leafy vegetables	pyridinylmethyl-benzamide	B5: cytoskeleton and motor proteins	delocalisation of spectrin-like proteins	43	RES	downy mildew
fluopyram	CG5: Brassica (cole) leafy vegetables	pyridinyl-ethyl-benzamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	powdery mildew, alternaria leaf spot, botrytis grey mould.
fluopyram + trifloxystrobin	CG5: Brassica (cole) leafy vegetables	pyridinyl-ethyl-benzamide + oximino-acetate	C2: respiration + C3: respiration	complex II: succinate-dehydrogenase + complex III:cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	7 + 11	R + R	sclerotinia rot (*Sclerotinia minor, S. sclerotiorum*), powdery mildew, alternaria leaf blight
fluxapyroxad	CG5: Brassica (cole) leafy vegetables	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	ring rot (*Mycosphaerella brassicicola*), suppression of alternaria leaf spot and sclcotinia stem rot
iprodione	cabbage (stored), cauliflower	dicarboximide	E3: signal transduction	MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	2	RE	alternaria
mandipropamid	CG5: Brassica (cole) leafy vegetables	mandelic acid amide	H5: cell wall biosynthesis	cellulose synthase	40	R	downy mildew

...continued

Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG) of Registration[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
oxathiapiprolin	Crop Subgroup 5A: Head and stem brassica	piperidinyl-thiazole isoxazoline	F9: lipid synthesis or transport / membrane integrity or function	lipid homeostasis and transfer / storage	49	R	downy mildew
Soil fumigant							
metam-sodium	ornamentals, food and fibre crops, tobacco	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8F[5]	RE	germinating weed seeds, perennial weeds (suppression), soil-borne fungal diseases, particularly damping-off and root rot (rhizoctonia, pythium, fusarium, phytophthora, verticillium, sclerotinia, oak root fungus, clubroot), nemtodes
oriental mustard seed meal (oil) (*Brassica juncea*)	CG5: Brassica (cole) leafy vegetables	diverse	not classified	unknown	N/C	R	root knot nematode, soil-borne *Pythium* spp. and *Fusarium* spp.

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). **The list includes all active ingredients registered as of February 14, 2018.** The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Crop groups as described in *Residue Chemistry Crop Groups* https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/protecting-your-health-environment/pesticides-food/residue-chemistry-crop-groups.html (accessed February 27, 2018).

[3]Source: Fungicide Resistance Action Committee. *FRAC Code List 2017: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed February 19, 2018).

[4]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2017-18, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2017-2022*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[5]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.3; July 2017)* (www.irac-online.org) (accessed February 19, 2018).

Black rot (*Xanthomonas campestris* pv. *campestris*)

Pest information

Damage: Black rot affects most crucifers and is considered one of the most serious bacterial diseases of brassica crops. Seedlings infected through contaminated seed may yellow, lose lower leaves and eventually die. Plants that survive seed infection may have reduced growth or die prematurely. Infections that occur through pores on leaf edges (hydathodes) cause V-shaped yellowing at the leaf margins. As the lesions expand, affected leaves become necrotic and drop. Infections tend to move along the vascular tissue, down the stem and into the roots causing blackening of small veins and vascular tissue. Under cool conditions, infected seedlings and plants may not show symptoms.

Life cycle: Black rot may be introduced into a field on infected seeds or transplants. The pathogen can also persist on plant residue for up to two years or until the material is completely decayed, and can survive in soil for up to 60 days. The pathogen is spread within a crop by wind, splashing water, field workers, on machinery and occasionally by insects. Extremely low levels of inoculum can cause serious epidemics. In the field, the pathogen infects plants through wounds and hydathodes on leaf margins. Following infection, the bacterium migrates into the xylem (water conducting tissues) and spreads throughout the plant. Warm wet weather favours disease development with the optimum temperature range being 25 to 30°C.

Pest management

Cultural controls: The use of certified, disease-free seeds or transplants will help prevent the introduction of the disease into the field. A hot water seed treatment will reduce the number of bacteria present in infested seeds. The use of sterilized flats and soilless mixes in the greenhouse helps in the production of disease-free transplants. The elimination of crop residues on the soil surface, the removal of cruciferous weeds and choosing fields on which brassica crops have not been grown for two to three years will reduce disease carry-over between crops. Planting in soils with good drainage and working in the fields when foliage is dry will help reduce spread of disease in the field. Additional management practices for black rot are listed in *Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: Tolerant cultivars of brassica vegetables are available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada* for pesticides registered for black rot control.

Issues for black rot

1. There is a need for the registration of reduced risk products for the control of black rot.
2. There is a need for the development of improved preventative strategies for black rot including resistant cultivars and seed treatments.

Blackleg (*Phoma lingam*)

Pest information

Damage: Symptoms of blackleg include circular grey lesions on leaves and sunken black cankers on stems. The cankers may girdle stems, spreading below the soil line and kill seedlings. On infected, surviving plants growth is stunted. Small fruiting bodies (pycnidia) become visible in leafspots and stem cankers.

Life cycle: The fungus can be carried on seed and survive in crop residue and soil in the field. Plants may become infected in the seedbed or in the field. In the spring, pycnida develop in infected tissues and release spores that are rain splashed and wind- blown to other susceptible plants and give rise to new infections.

Pest management

Cultural controls: Hot water treatments will destroy the pathogen carried in seed. The use of disease-free seed and transplants will eliminate a source of disease. Sanitation practices such as the elimination of crop residues and removing cull piles from fields will reduce disease carry-over between crops. It is important to not plant brassica vegetables near fields that had been planted to brassica crops the preceding season, which could be potential sources of inoculum. A crop rotation of four years out of brassica vegetable crops, canola or rapeseed, will enable the breakdown of crop residues and eliminate a source of the pathogen. The elimination of cruciferous weeds, potential hosts of blackleg, is also important to reduce disease carry-over between crops. Good water drainage and air circulation are important to reduce humidity in the canopy and make conditions less favourable for disease development.

Resistant cultivars: Varieties vary in their susceptibility to blackleg.

Control products: None available.

Issues for blackleg

1. There is a need for the registration of reduced risk products for the control of blackleg.

Clubroot (*Plasmodiophora brassicae*)

Pest information

Damage: Clubroot attacks most cultivated brassica crops. Early infections are difficult to detect, as symptoms begin underground. The pathogen infects the root and causes irregular swellings that restrict the flow of water and nutrients to above-ground plant parts. Above-ground symptoms vary from wilting, stunting and yellowing to early maturation.

Life cycle: The fungus persists in soil as resting spores which germinate in the presence of root exudates of susceptible plants. With germination, the resting spores release motile zoospores which infect the host plant through root hairs. The pathogen spreads throughout the plant roots inducing cell division and enlargement resulting in clubbed roots. Infected tissues give rise to new zoospores which cause continued spread of the disease. Resting spores, produced

in infected tissues, are released back into the soil as diseased tissues decay. The resting spores are extremely long lived in soil, surviving from 10 to 20 years and are the main means by which the fungus persists. The fungus can be spread in infected seedlings, contaminated manure, irrigation and drainage water, on farm implements and in soil blown by the wind and on the feet of animals and people. Clubroot can persist on cruciferous weeds such as wild mustard and shepherd's purse and in unrelated weeds such as sorrel, dock and bentgrass.

Pest management

Cultural controls: The use of non-infested soils in the production of transplants and planting into fields with no history of clubroot is important for preventing disease. In soils known to be contaminated, maintaining high levels of calcium and magnesium, and a pH above 7.2 will help prevent disease development. Long crop rotations with five to seven years between brassica crops must be followed. Weed control is important to remove potential hosts of the pathogen. Additional management practices for clubroot are listed in *Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada* for fungicides registered for the control of clubroot.

Issues for clubroot

1. There is a need for the development of an integrated approach to the management of clubroot that includes alternative methods such as trap crops.(Trap crops stimulate the germination of resting spores and infection of the crop, but are ploughed under before clubs and new resting spores are produced. As the pathogen does not complete its life cycle, levels of the clubroot population in the soil are reduced).
2. There is a need for the registration of control products for clubroot management in brassica crops.

Damping-off (*Pythium* spp., *Fusarium* spp., and *Rhizoctonia* spp.)

Pest information

Damage: The pathogens cause seed decay or seedling blight. Seedlings may fail to emerge or die shortly after emergence. Lesions may develop at the soil line causing the seedling to fall over. Rhizoctonia can cause lesions that girdle the stem causing it to become wire-like, a symptom called wirestem.

Life cycle: Damping-off pathogens survive in soil and in crop debris and can persist indefinitely. The disease is favoured by excessively wet soils, compacted soils and dense planting.

Pest management

Cultural controls: Strict sanitation during the production of transplants is important in preventing disease. The use sterilized trays and flats and disease-free soil will minimize the chances of introducing the pathogens. Planting into well-drained, disease-free soil and avoiding excessive irrigation and over-crowding of seedlings results in conditions much less favourable for disease development.

Resistant cultivars: None available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada* for fungicides available for the management of damping-off.

Issues for damping-off

None identified

Rhizoctonia diseases (wirestem, root rot, bottom rot, and head rot) (*Rhizoctonia solani*)

Pest information

Damage: Seedlings are the most susceptible to *Rhizoctonia solani*, however brassica crops can be affected throughout the growing season:

Wirestem: Early season infections may progress causing discolouration and constriction of seedling stems at the soil line resulting in a thin, wiry stem. Seedlings with wirestem are unlikely to survive transplanting to the field. Those that survive are stunted and have poor yields.

Bottom rot: Bottom rot affects mature cabbage and occurs when the outer leaves touch damp, infested soil. Lower leaves droop, decay, and turn black, but remain attached to the plant. Some plants may recover and produce heads.

Head rot: Between early head formation and maturity, a firm to slimy, dark decay of the bases of the outer leaves and heads develops, causing the outer leaves to drop, exposing the stem.

Root rot: The fungus may enter through leaf scars, injuries, or rootlets. Lesions on roots are usually dark brown, slightly sunken and semi-watery to spongy.

Life cycle: The pathogen can be seedborne and can survive in crop debris and soil. *R. solani* produces sclerotia that survive in the soil during unfavourable conditions. The fungus is spread by any means that moves soil from one place to another. Under suitable conditions, the sclerotia germinate and produce mycelium which infects plant tissues.

Pest management

Cultural controls: The use of treated seed and sterilized soil and flats in the production of seedlings will eliminate sources of disease. Spacing of seedlings that allows good air circulation and facilitates drying will reduce moisture conducive to these diseases. The use of disease-free transplants and adequate plant spacing in the field will also reduce disease development. Additional management practices for rhizoctonia diseases are listed in *Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada* for fungicides registered for the control of rhizoctonia diseases.

Issues for rhizoctonia diseases

1. There is a need for the registration of control products, including soil drenches, for the control of rhizoctonia diseases in brassica crops.

Bacterial (peppery) leaf spot (*Pseudomonas syringae* pv. *maculicola*)

Pest information

Damage: This disease is more prevalent on cauliflower but can also affect broccoli and Brussels sprouts. Early symptoms are small spots (one mm) associated with stomata that develop on older leaves. Spots eventually develop a yellow halo and with time coalesce to form brown papery areas that become ragged. Leaves may become puckered due to lesions on veins which restrict growth.

Life cycle: The pathogen may be carried on infested seed and in plant debris and can survive in soil for two to three years. It is spread by splashing water. Cool, wet weather favours disease development.

Pest management

Cultural controls: Hot water treatments will eliminate the pathogen from seed. The use of seedbeds and fields in which brassica crops have not been planted for at least three years and the elimination of brassica crop residues after harvest will reduce the chances of disease carry-over between crops.

Resistant cultivars: None available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada* for pesticides available for the management of bacterial leafspot.

Issues for bacterial (peppery) leafspot

None identified.

Grey leaf spot *(Alternaria brassicae)* and black leaf spot *(A. brassicola)*

Pest information

Damage: Alternaria diseases can affect many brassica vegetables and cause yellow and brown spotting on leaves and heads. *A. brassicae* lesions are small and light brown or grey (grey leaf spot), while *A. brassicicola* lesions are larger and darker (black leaf spot). With time, the spots enlarge and become brown and covered with spores.

Life cycle: A. brassicae and *A. brassicicola* survive between seasons as spores on the seed coat, as mycelium in seed as well as in infected plant debris and on cruciferous weeds. Field infections may arise from seed-borne inoculum as well as wind-blown spores produced in infected crop debris and weeds. Extended periods of leaf wetness favour infection. Spores are produced in leafspots and disseminated by wind, water, tools and animals throughout the growing season.

Pest management

Cultural controls: Hot water treatment will destroy alternaria carried in or on seed. In the field, infections can be reduced with proper plant spacing that facilitates air movement and drying of the plants, as extended periods of leaf wetness are conducive to infection. Adequate spacing of plants will also minimize spread of the disease by splashing of water droplets between plants. The avoidance of irrigation during head development will help in the control of these diseases. Long crop rotations, field sanitation and control of weeds will reduce disease carry-over. Additional management practices for grey leaf spot and black leaf spot are listed in *Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada* for fungicides registered for the control of alternaria diseases.

Issues for grey leaf spot and black leaf spot

1. There is a need for the registration of new chemistries with short pre-harvest intervals for the control of foliar diseases of brassica crops.

Downy mildew (*Hyaloperonospora parasitica*)

Pest information

Damage: Most cultivated brassica vegetables are susceptible to downy mildew which attacks both seedling and mature plants. The disease is particularly damaging to young seedlings which develop yellowing of true leaves and cotyledons. Fluffy white growth develops on the underside of affected leaves. Later in the season, older leaves may be affected and spotting will develop on the heads of cabbage and cauliflower. Grey streaking may develop inside the curds of cauliflower and broccoli floral heads. Heads of cabbage affected by downy mildew are more prone to storage rots.

Life cycle: The fungus overwinters as oospores in crop debris and on cruciferous weeds. Disease development is favoured by cool temperatures (between 10°C and 15°C), prolonged periods of leaf wetness and high humidity, such as after drizzle, or during periods of heavy dew or fog. Under suitable conditions, symptoms can develop within four days of infection. Spores produced within infected tissues are wind-blown to new plants where they cause new infections.

Pest management

Cultural controls: Planting into seedbeds that do not have a history of downy mildew and in fields that have not had crucifers for at least two years, will minimize the chances of disease development. Management practices that reduce the duration of foliar wetness such as avoiding excessive irrigation and adequate spacing of seedlings will make conditions less suitable for downy mildew. It is important to destroy residues of brassica crops, and cruciferous weeds to prevent the spread and overwintering of the disease.

Resistant cultivars: A few broccoli varieties are resistant to downy mildew.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada* for fungicides registered for the control of downy mildew.

Issues for downy mildew

1. The registration of products with new modes of action is required for the control of downy mildew and for resistance management.

Fusarium wilt (yellows) (*Fusarium oxysporum* f.sp. *conglutinans*)

Pest information

Damage: Fusarium wilt can affect most brassica vegetables. Infected seedlings become yellow and die within a few weeks of transplanting. Older plants become stunted and yellowed, drop lower leaves and develop a dark discolouration of leaf veins. Symptoms are often more pronounced on one side of a plant. Losses caused by fusarium wilt can be significant during warm growing seasons.

Life cycle: The pathogen is soil-borne and can infect plants at any growth stage. Plants are infected through seedling rootlets damaged by transplanting, with the pathogen moving directly into the xylem tissue. The pathogen produces conidia and chlamydospores (resting spores) both on the inside and outside of the infected tissues. Disease development is favoured by warm weather and soil temperatures between 27 and 29 °C. The pathogen is inhibited at temperatures below 16 °C and above 32 °C. The fungus can survive in the soil for many years. Short distance spread occurs via surface water, wind-blown soil and farm equipment. The fungus can persist in the soil in the absence of host plants.

Pest management

Cultural controls: The use of disease-free seed and seedlings and planting only resistant varieties will help minimize disease development. Additional management practices for fusarium wilt are listed in *Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: Resistant varieties are available for cabbage.

Control products: None available.

Issues for fusarium wilt

1. There is need for further work on preventative controls for fusarium yellows including the development of resistant cultivars and soil drenches.

Head rot (*Pectobacterium* spp. and *Pseudomonas* spp.)

Pest information

Damage: Symptoms of head rot first appear as water soaked lesions on heads and leaves of brassica plants. As lesions enlarge, tissues beneath the lesions become discoloured, soft and watery. Under suitable conditions of temperature and humidity, extensive decay can develop. Decay can develop in the field, in transit or in storage.

Life cycle: The bacteria survive in soil and may be present in ponds and other irrigation sources. The bacteria are spread by insects, on tools and in infected plant debris, soil and water. During heavy rainfalls, the pathogens are spread by splashing water. The bacteria are secondary invaders and infect through wounds caused by hail, tools (physical injury) and insects. Once infection has occurred, the bacteria spread into healthy tissue. Disease development is favoured by warm, humid conditions and prolonged wetness of plant tissues. Under dry conditions, the progress of infections halts, but once wetting or high humidity occurs, infections spreads rapidly. The bacteria grow best at temperatures around 28 °C.

Pest management

Cultural controls: Cultural practices that promote drying of the crop canopy and minimize the duration of foliar wetness, such as wider row spacing and planting in well drained soils, will reduce the potential for the development of head rot. Avoiding excessive applications of nitrogen that contribute to lush growth that decreases air movement within the canopy and increases the drying time for plant tissue will also help to minimize disease. Insect control is important to reduce potential sites of infection. Rotation with crops less susceptible to the disease will also minimize disease levels in the field. Proper disinfection of storage and containers, discarding of infected plants and providing adequate ventilation to prevent moisture on plant surfaces, will reduce disease development in storage.

Resistant cultivars: None available

Control products: None available.

Issues for head rot

1. There is a need for the registration of control products for bacterial diseases of brassica crops.

Sclerotinia rot (*Sclerotinia sclerotiorum*)

Pest information

Damage: Early infections of sclerotinia rot (otherwise referred to as cottony soft rot) appear as water soaked areas on the lower stems and leaves that have come into contact with the soil. As the lesions expand, the infected leaves wilt and the fungus spreads to other parts of the plant. The development of white, cottony mycelium in infected tissues is common. Infected heads of cabbage develop an internal watery soft rot. Sclerotinia can cause losses in the field and in storage.

Life cycle: The pathogen has a broad host range and can infect over 350 types of plants. The pathogen overwinters in infected plant material and can survive for many years in the soil as sclerotia (resting bodies). Sclerotia germinate to produce mycelium or fruiting bodies called apothecia which release ascospores that are wind-blown to new plants where they cause infection. The disease can also spread during storage or transit if suitable storage temperatures are not maintained.

Pest management

Cultural controls: Rotation for three to four years with non-susceptible crops, such as corn, cereal or grasses, will significantly decrease the number of viable sclerotia in the soil. Planting on well-drained soil and good weed management will reduce disease development. Cleaning harvested plants and storage bins of soil will reduce the spread of inoculum.

Resistant cultivars: None available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada* for fungicides registered for the control of sclerotinia rot in brassica crops.

Issues for sclerotinia rot

1. The development of alternative approaches to the management of sclerotinia rot is required. There is a need for the registration of fungicides for the control of sclerotinia rot and the development of effective application methods.
2. There is a need for the development of brassica cultivars with resistance to sclerotinia rot.

Grey mould (*Botrytis cinerea*)

Pest information

Damage: Botrytis can attack cabbage in storage causing grey-green water soaked lesions on which masses of brownish spores develop.

Life cycle: The pathogen can affect many fruits and vegetables. It attacks injured, weakened and senescing tissues. Botrytis produces abundant grey-brown spores (conidia) on the surface of infected tissues. It survives in soil and plant debris as mycelium and sclerotia. It is active at temperatures as low as 0°C in storage.

Pest management

Cultural controls: To minimize disease it is important to place only mature, healthy cabbage in storage and to avoid storing heads with insect feeding, sunscald or other injuries. Proper temperature and humidity conditions must be maintained in storage.

Resistant cultivars: None available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada* for fungicides available for the management of grey mould in brassica crops.

Issues for grey mould

None identified.

Insects and Mites

Key issues

- There is a need for the development of effective strategies for the management of root maggots in brassica crops.
- There is a need for the registration of reduced risk insecticides and biopesticides in new chemical families, for the management of a number of insect pests in brassica crops. The phase-out of older chemistries is of concern as this will reduce the numbers of chemical groups available for pesticide rotation and resistance management.
- New strategies are required for the management of insects such as thrips and Swede midge that feed internally in brassica crops and are difficult to control using conventional methods.

Table 7. Occurrence of insect pests in broccoli and cabbage crops in Canada[1,2]

Insect	Cabbage			Broccoli	
	British Columbia	Ontario	Quebec	Ontario	Quebec
Cabbage maggot					
Cutworms					
Flea beetle					
Swede midge					
Aphids					
Cabbage aphid					
Tarnished plant bug					
Thrips					
Caterpillars					
Imported cabbageworm					
Diamondback moth					
Cabbage looper					
Leafminer					
Slugs					

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest not present.

Data not reported.

[1]Source: Brassica crop stakeholders in reporting provinces. The data reflect the 2015, 2014 and 2013 production years.

[2]Refer to Appendix 1 for further information on colour coding of occurrence data.

Table 8. Adoption of insect management practices for broccoli and cabbage production in Canada[1]

	Practice / Pest	Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetle	Swede midge
Avoidance	Resistant varieties					
	Planting/ harvest date adjustment					
	Crop rotation					
	Choice of planting site					
	Optimizing fertilization					
	Reducing mechanical damage					
	Thinning/ pruning					
	Trap crops/ perimeter spraying					
	Physical barriers					
Prevention	Equipment sanitation					
	Mowing/ mulching/ flaming					
	Modification of plant density (row or plant spacing; seeding rate)					
	Seeding depth					
	Water/ irrigation management					
	End of season crop residue removal/ management					
	Pruning out/ removal of infested material throughout the growing season					
	Tillage/ cultivation					
	Removal of other hosts (weeds/ volunteers/ wild plants)					
Monitoring	Scouting/ trapping					
	Records to track pests					
	Soil analysis					
	Weather monitoring for degree day modelling					
	Use of portable electronic devices in the field to access pest identification /management information					
	Use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					

...continued

Table 8. Adoption of insect management practices for broccoli and cabbage production in Canada[1] (continued)

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetle	Swede midge
Decision making tools	Economic threshold					
	Weather/ weather-based forecast/ predictive model (eg. degree day modelling)					
	Recommendation from crop specialist					
	First appearance of pest or pest life stage					
	Observed crop damage					
	Crop stage					
Suppression	Pesticide rotation for resistance management					
	Soil amendments					
	Biopesticides					
	Release of arthropod biological control agents					
	Habitat management to enhance natural controls					
	Ground cover/ physical barriers					
	Pheromones (eg. mating disruption)					
	Sterile mating technique					
	Trapping					
	Targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					
Crop specific Practices	Use of exclusion fencing					
	Use of floating row covers (mesh nets)					

This practice is used to manage this pest by at least some growers.

This practice is not used by growers to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]Source: Brassica vegetable (cabbage and broccoli) stakeholders in reporting provinces (Ontario and Quebec). The data reflect the 2015, 2014 and 2013 production years.

Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
acetamiprid	CG5: Brassica (cole) leafy vegetables	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	R	aphids, Swede midge
acephate	Brussels sprouts, cabbage, cauliflower	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RES*	cabbage looper, imported cabbageworm, diamondback moth, green peach aphid
triethalkanolamine salts of fatty acids	vegetables	not classified	unknown	N/A	R	aphids, mealybugs, spider mites, whiteflies, soft brown scale, psyllids, rose and pear slugs, earwigs
Bacillus thuringiensis subsp. *aizawai, Strain ABTS-1857*	Crop subgroup 5-13 (5A): Head and stem Brassica	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptors of insect midgut membranes	11A	R	cabbage looper, cross-striped cabbageworm, diamondback moth, imported cabbageworm
Bacillus thuringiensis subsp. *kurstaki* strain ABTS-351	broccoli, cabbage	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptor of insect midgut membranes	11A	R	cabbage looper, diamondback moth, imported cabbageworm
Bacillus thuringiensis subsp. *kurstaki* strain ABTS-351	cauliflower	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptor of insect midgut membranes	11A	R	cabbage looper, imported cabbageworm
Bacillus thuringiensis subsp. *kurstaki* strain EVB113-19	broccoli, Brussels sprouts, cabbage, cauliflower	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptor of insect midgut membranes	11A	R	cabbage looper, diamondback moth, imported cabbageworm

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Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Bacillus thuringiensis subsp. *kurstaki* strain SA-12	broccoli, Brussels sprouts, cabbage, cauliflower	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptor of insect midgut membranes	11A	R	cabbage looper, diamondback moth, imported cabbageworm
Baculovirus: *Autographa californica* nucleopolyhedrovirus FV11 (ACMNPV)	Crop subgroup 5-13 (5A): Head and stem Brassica (for use in greenhouses)	biological	unknown	N /A	R	cabbage looper
Beauvaria bassiana strain ANT-03	greenhouse vegetables	biological	unknown	N/A	R	whiteflies, aphids, thrips
canola oil	broccoli, cabbage, cauliflower, kale	not classified	unknown	N/A	R	aphids, mealybugs, mites, scales, whiteflies
carbaryl	broccoli, Brussels sprouts, cabbage, cauliflower	carbamate	acetylcholinesterase (AChE) inhibitor	1A	RES	flea beetles, leafhoppers, armyworms, corn earworm, diamondback moth (larvae), imported cabbageworm, lygus bugs, meadow spittlebug, stinkbugs, cabbage looper,
chlorantraniliprole	CG5: Brassica (cole) leafy vegetables	diamide	ryanodine receptor modulator	28	R	imported cabbage worm, diamondback moth, cabbage looper, black cutworm, armyworm, fall armyworm, beet armyworm, corn earworm, leafminers
chlorantraniliprole + lambda-cyhalothrin	Crop subgroup 5A: Head and stem Brassica	diamide + pyrethroid, pyrethrin	ryanodine receptor + sodium channel modulator	28 + 3A	R + RE	onion thrips, black cutworm, armyworm, fall armyworm, beet armyworm, corn earworm, liriomyza leafminers

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Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
chlorpyrifos	broccoli, Brussels sprouts, cabbage, cauliflower	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	cabbage maggot, black cutworm darksided cutworm, redbacked cutworm, subterranean cutworms
clothianidin + imidacloprid	CG5: Brassica (cole) leafy vegetables (seed treatment)	neonicotinoid + neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator + nicotinic acetylcholine receptor (nAChR) competitive modulator	4A + 4A	RES* + RES*	aphids, flea beetle
cyantraniliprole	CG5: Brassica (cole) leafy vegetables	diamide	ryanodine receptor modulator	28	R	imported cabbageworm, diamondback moth, cabbage looper, flea beetles (early season damage reduction) Swede midge (early season damage reduction), cabbage maggot, fall armyworm, beet armyworm, cutworms, corn earworm, aphids, dipteran leafminers (larvae)
cyantraniliprole + thiamethoxam	CG5: Brassica (cole) leafy vegetables	diamide + neonicotinoid	ryanodine receptor modulator + nicotinic acetylcholine receptor (nAChR) competitive modulator	28	R + RES*	aphids, dipteran leafminers, flea beetles; early season control of cabbage looper, diamondback moth and imported cabbageworm; early season suppression of flea beetles and thrips; reduces damage caused by beet armyworm, corn earworm fall armyworm and yellowstriped armyworm
cyclaniliprole	Crop subgroup 5-13 (5A): Head and stem Brassica	diamide	ryanodine receptor modulator	28	R	beet armyworm, Bertha armyworm, cabbage looper, diamondback moth, leafminers, western flower thrips (suppression), whiteflies (suppression)

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Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
cypermethrin	broccoli, Brussels sprouts, cabbage, cauliflower	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	imported cabbageworm, cabbage looper, diamondback moth larvae, flea beetles, thrips, cutworms (black, white, darksided, redbacked, army and pale western)
deltamethrin (Prairie provinces and Peace River region of British Columbia only)	broccoli, Brussels sprouts, cabbage, cauliflower	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	cabbageworm, cabbage looper, diamondback moth
deltamethrin (eastern Canada and British Columbia)	broccoli, Brussels sprouts, cabbage, cauliflower	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	cabbageworm, cabbage looper, diamondback moth, flea beetle (cabbage only)
deltamethrin + imidacloprid	Crop subgroup 5A: Head and stem Brassica	pyrethroid, pyrethrin + neonicotinoid	sodium channel modulator + nicotinic acetylcholine receptor (nAChR) competitive modulator	3 + 4	RE + RES*	imported cabbageworm, diamondback moth, cabbage looper, crucifer flea beelte, aphids
dichlorvos plus related active compounds	for use as a toxicant in commercial insect traps	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RES*	for use as a toxicant in commercial insect traps only; for lepidopterous pests of vegetable crops
dimethoate	broccoli, Brussels sprouts, cauliflower	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	R	aphids
ferric phosphate	vegetables	not classified	unknown	N/A	R	slugs, snails
ferric sodium ethylenediamine tetra acetic acid (EDTA)	vegetables	not classified	unknown	N/A	R	slugs, snails

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Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
flonicamid	CG5: Brassica (cole) leafy vegetables	flonicamid	chlordotonal organ modulator - undefined target site	29	R	aphids
flupyradifurone	Crop sub group 5-13 (5A): Brassica head and stem vegetabels	butenolide	nicotinic acetylcholine receptor (nAChR) competitive modulator	4D	R	aphids, whiteflies
imidacloprid (soil application)	CG5: Brassica (cole) leafy vegetables	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	aphids (cabbage aphid, green peach aphid, turnip aphid), leafhoppers (suppression)
imidacloprid (for vegetable plants grown in greenhouses) (transplant tray plug drench	Crop subgroup 5A: Head and stem brassica	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	Swede midge
imidacloprid + deltamethrin	Crop subgroup 5A: Head and stem brassica	neonicotinoid + pyrethroid, pyrethrin	nicotinic acetylcholine receptor (nAChR) competitive modulator + sodium channel modulator	4A	RES* + RE	imported cabbageworm, diamondback moth, cabbage looper, crucifer flea beetle, aphids
lambda-cyhalothrin	subgroup	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	Swede midge, cabbage looper, onion thrips, crucifer flea beetle, diamondback moth larvae, imported cabbageworm
malathion	broccoli, Brussels sprouts, cabbage	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	R	aphids, cabbage loopers, imported cabbageworm, spider mites, leafhopper, cucumber beetle, flea beetles
malathion	cauliflower	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	R	aphids, cabbage loopers, imported cabbageworm,

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Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
metaldehyde	cabbage	not classified	unknown	N/A	R	slugs, snails
metam-sodium	ornamentals, food and fibre crops, tobacco	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	8F	RE	germinating weed seeds, symphylans (garden centipede), soil-borne fungal diseases and nematodes, suppression of perennial weeds
methomyl	broccoli, cabbage, cauliflower	carbamate	acetylcholinesterase (AChE) inhibitor	1A	RE	cabbage looper, imported cabbageworm, diamondback moth
methomyl	Brussels sprouts	carbamate	acetylcholinesterase (AChE) inhibitor	1A	RE	cabbage looper, imported cabbageworm, diamondback moth, slugs
methoxyfenozide	CG5: Brassica (cole) leafy vegetables	diacylhydrazine	ecdysone receptor agonist	18	R	cabbage looper, imported cabbageworm, diamondback moth (suppression)
naled	broccoli, Brussels sprouts, cauliflower	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RES	imported cabbageworm, diamondback moth, aphids, cabbage looper
novaluron	Crop subgroup 5A: Head and stem brassica	benzoylurea	inhibitor of chitin biosynthesis, type 0	15	R	cabbage looper, imported cabbageworm, diamondback moth

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Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
permethrin	broccoli, Brussels sprouts, cabbage, cauliflower	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	cabbage looper, imported cabbageworm, diamondback moth larvae, crucifer flea beetle
potassium salts of fatty acids	on vegetables (broccoli, Brussels sprouts, cabbage, cauliflower	not classified	unknown	N/A	R	aphids, spider mites, whiteflies
spinetoram	Crop subgroup 5-13 (5A): Head and stem brassica	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric modulator	5	R	diamondback moth, cabbage looper, imported cabbageworm
spinosad	Crop subgroup 5-13 (5A): Head and stem brassica	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric modulator	5	R	cabbage looper, imported cabbageworm, diamondback moth, suppression of crucifer flea beetle and thrips, reduction in damage from Swede midge
spiromesifin	Crop subgroup 5-13 (5A): Head and stem Brassica	tetronic and tetramic acid derivative	inhibitor of acetyl CoA carboxylase	23	R	whiteflies (silverleaf, sweet potato, greenhouse)

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Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
spirotetramat	CG5: Brassica (cole) leafy vegetables	tetronic and tetramic acid derivative	inhibitor of acetyl CoA carboxylase	23	R	aphids, whiteflies, Swede midge larvae
sulfoxaflor	CG5: Brassica (cole) leafy vegetables	sulfoximine	nicotinic acetylcholine receptor (nAChR) competitive modulator	4C	R	aphids
thiamethoxam	CG5: Brassica (cole) leafy vegetables	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	aphids, early season suppression of flea beetles

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). **The list includes all active ingredients registered as of February 15, 2018.** The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Crop groups as described in *Residue Chemistry Crop Groups* https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/protecting-your-health-environment/pesticides-food/residue-chemistry-crop-groups.html (accessed February 27, 2018).

[3]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.3; July 2017)* (www.irac-online.org) (accessed February 19, 2018).

[4]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2017-18, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2017-2022*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

Aphids: Cabbage aphid (*Brevicoryne brassicae*) and green peach aphid (*Myzus persicae*)

Pest information

Damage: Aphids have piercing and sucking mouthparts through which they injest plant juices. Feeding by high populations on seedlings can result in stunting. The presence of aphids, cast skins and honeydew on the harvested crop will reduce its marketability. The cabbage aphid injects a toxin while feeding that causes yellowing and cupping of leaves. Aphids are vectors of virus diseases including the turnip mosaic virus.

Life cycle: The green peach aphid overwinters in the egg stage on twigs of *Prunus* spp. Eggs hatch in the spring and the aphid develops through several generations before dispersing to other hosts, including brassica crops. The cabbage aphid overwinters as eggs on plant debris. Eggs hatch in the spring giving rise to females that are able to reproduce without mating and bear live young. Hot, dry weather favours insect development. There are several generations a year. Males are produced in the fall only. Each female lays up to 100 eggs in the crevices on cabbage leaf undersides.

Pest management

Cultural controls: Burying crop residues at the end of the growing season will promote their decay and eliminate overwintering sites of the cabbage aphid. Seedlings transplanted to the field in the spring must be free of aphids. Avoiding excessive nitrogen applications which promote excessive plant growth will make conditions less suitable for aphids. Many natural predators and parasites help to keep aphid populations in check. However, natural enemies are not usually sufficient to provide complete control of cabbage aphids.

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada* for insecticides registered for aphids in brassica crops.

Issues for aphids

None identified.

Leafminer (*Liriomyza* spp.)

Pest information

Damage: Female flies feed on plant sap and create puncture marks on leaves during feeding and egg laying activities. Larvae feed between the upper and lower leaf surfaces, resulting in serpentine mines in leaf tissues. The leaf mines can reduce the photosynthetic ability of the plant, provide entry sites for pathogens and affect the marketability of the crop. Seedlings are more susceptible to leafminer injury due to their small leaf area.

Life cycle: The adult fly lays eggs singly within the leaf tissues of the brassica plant. Larvae feed within the leaf and when fully grown, exit the leaf to pupate and become adults. The development of the insect is affected by temperature with the life cycle taking as little as two weeks if temperatures are warm.

Pest management

Cultural controls: Yellow sticky traps can be used to monitor adult fly populations. Weed control is important to eliminate other hosts of this pest. The removal or burial of crop debris immediately after harvest will reduce the numbers of emerging leafminer flies and eliminate a source of the overwintering population. Rotation with crops not susceptible to leafminers will help reduce populations in the field.

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada* for insecticides registered for the control of leafminers in brassica crops.

Issues for leafminer

1. The registration of additional control products for the management of leafminers is required. It is important that new products be in various chemical groups for resistance management as leafminer can develop resistance to pesticides quickly.

Caterpillars: Imported cabbageworm (*Pieris rapae*), diamondback moth (*Plutella xylostella*) and cabbage looper (*Trichoplusia ni*)

Pest information

Damage: Caterpillars are common pests of all brassica crops. Young larvae of the imported cabbageworm and cabbage looper feed on lower leaf surfaces while older larvae cause large, irregular holes in leaves. Diamondback larvae cause small "window-like" holes in leaves as they do no tend to eat through both leaf surfaces. Feeding by these insects can damage the heads of broccoli and cauliflower. Feeding on young plants has a greater impact on yield. The presence of feeding injury and frass can render heads unmarketable.

Life cycle: Cabbage loopers and diamondback moths generally are carried into Canada on winds from the south, while the imported cabbageworm does overwinter in Canada. Adult moths lay eggs directly on the foliage of brassica plants. Larvae are present throughout the season due to the overlapping generations of various species. There are usually three generations of the imported cabbageworm and all generations can be damaging. Of the two to six diamondback moth generations, the first is most damaging because the crop is in the seedling stage. The second generation rarely causes economic damage. There may be up to three generations per year of the cabbage looper and damage from each of the generations can cause severe defoliation if left unchecked.

Pest management

Cultural controls: The removal of cull piles and cruciferous weeds (such as wild mustard and shepherd's purse) that serve as alternate hosts for these pests will eliminate potential overwintering sites. There are a number of natural predators and parasitoids that help to reduce populations of caterpillars in brassica crops. Cabbage loopers and imported cabbageworms may also be killed by a natural virus disease. Monitoring for caterpillars is done by visual inspection and counting of larvae on individual plants. Adult moths may also be monitored through the use of light traps or pheromone traps however treatment thresholds based on the average number of larvae per plant is considered the most accurate. Additional management practices for imported cabbageworm and diamondback moth are listed in *Table 8. Adoption of insect management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada* for insecticides registered for the management of caterpillar pests in brassica vegetable crops.

Issues for caterpillars

1. There is a need for the registration of control products with different modes of action for resistance management.
2. There is concern that with the phasing out of older chemistries such as the organophosphates and carbamates, and the limited effectiveness of pyrethroids during intense summer heat, that there will be insufficient chemistries available for resistance management.

Cutworm (family Noctuidae)

Pest information

Damage: Cutworms feed on foliage and stems of seedlings and transplants in early spring, often severing the plants at or below the soil surface and causing them to fall over.

Life cycle: The various cutworm species may overwinter as eggs, half-grown larvae or pupae in soil and under crop debris and some species do not overwinter in Canada but are brought in on winds from the United States. Adult moths lay eggs on weeds and in soil in weedy areas before brassica crops are planted. Following hatching or emergence from the soil, larvae feed on weeds and may move into a brassica crop to feed. When larvae are full grown, they move into the soil to pupate.

Pest management

Cultural controls: Fields can be monitored in the spring by checking for holes in foliage, seedlings that have wilted or fallen over and "misses" in the field. Cutworms hide during the day and can often be found in the soil at the base of affected seedlings. Good weed control in the early spring will make fields less attractive to female moths for egg-laying.

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada* for insecticides registered for cutworm control.

Issues for cutworm

None identified.

Cabbage maggot (*Delia radicum, Delia* spp.)

Pest information

Damage: Cabbage maggot (*Delia radicum)* is a major pest of all brassica vegetable crops. Other species of *Delia* have also been associated with cabbage maggot- type injury and are included by some under the name "cabbage maggot'. Cabbage maggot larvae feed on plant roots decreasing the vigour of the plants and providing entry sites for secondary pathogens. Seedlings and transplants are most susceptible to injury given their smaller root systems and often are killed by root maggot attack. Above-ground symptoms of attack include a yellowing and purpling of the upper, outer leaves.

Life cycle: Cabbage maggots overwinter as pupae in the soil. Adult flies emerge in the spring, mate and female flies lay eggs on stems or in the soil near young plants. Following hatching, the maggots feed on roots of seedlings and when full grown three to five weeks later, pupate in the soil. Adult flies emerge and again lay eggs on or near brassica plants. The cabbage maggot has one to three generations per year, but only the first generation is economically damaging.

Pest management

Cultural controls: A two to three year crop rotation out of crucifer crops is important for control. Tillage prior to seeding can reduce the level of emergence of adult flies by moving pupae closer to the soil surface where they are more susceptible to attack by natural enemies. Minimizing surface residues, keeping cull piles away from fields and disking/ploughing under residues to depths greater than five cm is required to reduce maggot populations. The use of insect netting has been shown to be very effective. Monitoring can be done by checking for eggs at the base of seedlings. When soil conditions are dry, many eggs abort and chemical control is not required. The use of kale as a trap crop can be effective on small fields if managed properly. The Pesticide Risk Reduction Program of AAFC has information available regarding pest management and pesticide risk reduction issues for cabbage maggot in brassica crops (www.agr.gc.ca/eng/?id=1288805416537). Additional management practices for cabbage maggot are listed in *Table 8. Adoption of insect management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada* for insecticides registered for cabbage maggot control.

Issues for cabbage maggot

1. There is a need for the registration of new products that control cabbage maggot populations and that are in different chemical families for use in resistance management.
2. There is a need for the continued research and development of effective strategies for the management of the various root maggot species that attack brassica crops.

Flea beetles (*Phyllotreta spp.*): Crucifer flea beetle (*P. cruciferae*)

Pest information

Damage: Flea beetles feed on leaves, causing typical 'shot hole' damage. Seedlings can be killed by heavy feeding. Larger plants have a much greater leaf surface area and can tolerate more feeding damage. Severe injury can occur if the beetles feed on the growing point of the plant. Flea beetles can spread black rot.

Life cycle: Adult flea beetles overwinter in leaf litter and emerge in early spring. They feed on cruciferous weeds, canola and volunteer crops as they emerge. Adults lay eggs near the roots of host plants. Larvae feed and develop on the roots and then pupate in the soil. By late July adults emerge from soil and begin to feed on foliage. Flea beetles have one generation per year.

Pest management

Cultural controls: Monitoring up to the six leaf stage is critical as young plants can tolerate no more than one beetle per plant. Row covers can be used to protect early plantings. Indian mustard, used as a trap crop, can reduce damage on cabbage, broccoli and cauliflower to below economic thresholds. The removal of volunteer brassica plants and weeds decreases alternate hosts that can harbour populations. Additional management practices for flea beetles are listed in *Table 8. Adoption of insect management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada* for insecticides registered for flea beetle control.

Issues for flea beetles

1. The registration of reduced risk products in different chemical families is needed for the control of flea beetles in brassica crops.

Swede midge (*Contarinia nasturtii*)

Pest information

Damage: Swede midge larvae feed in groups near the growing point of the plant causing tissues to become swollen, distorted and twisted. The growing point may be killed resulting in a blind head or in the development of secondary stems. Corky scarring may develop along petioles and stems. When larvae feed on older plants, they can cause twisting of the head and crinkled heart leaves. Infested plants produce no marketable yield.

Life cycle: The insect overwinters as pupae and the first generation adults emerge in the spring. The female lays two to fifty eggs in clusters on the growing vegetative tissue near the growing point of the host plant. After egg hatch, larvae feed on plant tissue. When full grown, they drop to the ground and tunnel below the soil surface to spin cocoons and pupate. Adults will emerge from the soil in about two weeks depending on weather conditions. There are four to five overlapping generations per year.

Pest management

Cultural controls: Crop rotation in which brassica crops are not planted for three to five years, is very important to prevent the build-up of high populations of Swede midge. In addition, not planting brassica crops in adjacent fields during the period of the rotation will also help to prevent the build-up of midge populations. It is important to control brassica weeds to remove alternate hosts. The use of pest-free transplants will reduce the potential for the introduction of the pest into the field. Pheromone traps are commercially available to monitor Swede midge and help time treatments. Traps must be checked frequently due to the short generation time of the midge. Additional management practices for Swede midge are listed in *Table 8. Adoption of insect management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada* for insecticides registered for Swede midge control.

Issues for Swede midge

1. There is a need for the development of improved approaches to the management of Swede midge.
2. There is a need for the registration of control products with shorter pre-harvest intervals for the management of Swede midge. Control products that can be used early in the season in greenhouses for transplant production are also required for this pest.

Thrips (*Thrips tabaci*)

Pest information

Damage: Feeding by thrips can cause serious economic losses of cabbage crops due to the resulting decreased marketability of the heads. Thrips feed with their rasping and sucking mouth parts which results in roughened areas on leaves. The damaged tissues are susceptible to secondary fungal or bacterial infections. In cabbage fields, thrips are located on the surface of outer leaves, but as plants form heads, they can remain between leaves. This habit is of concern for stored cabbage, as thrips can survive at low temperatures and continue to cause feeding damage.

Life cycle: Early in the season, thrips prefer grasses, alfalfa and clover, but as these are cut and dry up, thrips migrate to brassica crops. On brassica crops, the female thrips inserts eggs into leaf tissues. After hatching, nymphs develop through four stages and become adults. Females can reproduce without mating. Thus populations can expand rapidly. Thrips return to winter wheat and alfalfa where both adults and nymphs overwinter.

Pest management

Cultural controls: Monitoring cabbage fields that are closest to preferred host crops (grasses, alfalfa and clover) will enable the early detection of thrips. Irrigation with larger water droplet size can knock the thrips off the plants. Several natural enemies such as the minute pirate bug (*Orius insidious*) are voracious predators of thrips.

Resistant cultivars: There are varieties available with some degree of tolerance to thrips feeding.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada* for insecticides available for thrips control.

Issues for Thrips

1. There is a need for the registration of new products in different chemical families for resistance management for thrips. Products are required that will control thrips present on the inner leaves of cabbage.
2. The development of new techniques and strategies is required for improved management of thrips.

Tarnished plant bug (*Lygus lineolaris*)

Pest information

Damage: The tarnished plant bug is an occasional pest of broccoli and cauliflower, but because it damages the marketable portion of the crop, detection is very important. Feeding by both adults and nymphs causes dry, shrivelled, greyish to brown florets scattered across the head of broccoli and brown streaking on the curd of cauliflower. Bacterial and fungal rots may invade damaged tissues.

Life cycle: The tarnished plant bug has a broad host range, but certain plants such as mints, chickweed, pigweed and alfalfa are favourite hosts. Winter is spent as an adult in hedgerows, weedy areas and woods. Eggs are laid on preferred hosts in the spring. After hatching, nymphs develop through five instars (stages) to become adults.

Pest management

Cultural controls: Controlling weeds in a field will eliminate refuges for early season populations. It is important to monitor nearby alfalfa fields for populations that potentially could move into the brassica crop, once the alfalfa has been cut. Since nymphs are much less mobile than adults, it is preferable to cut alfalfa crops before the tarnished plant bug reaches the adult stage on this crop.

Resistant cultivars: None available.

Control products: None available.

Issues for tarnished plant bug

1. There is a need for the registration of reduced risk products for the control of tarnished plant bug.

Slugs (Various species)

Pest information

Damage: Slug damage is most common in mid to late summer when a heavy crop canopy shades the soil, creating a moist microclimate required by slugs. Slugs skeletonize leaves and eat large ragged holes in leaves. Trails of dried slime are evidence of slugs. Slugs may feed at the base of plants often damaging the roots of crops.

Life cycle: Slugs overwinter as adults or eggs. Hatching occurs in the early spring. Slugs require a moist environment to survive, thriving under cool, wet conditions. They feed at night and hide in soil and under debris during the day.

Pest management

Cultural controls: The control of weeds, elimination of plant debris on the soil surface, cultivation and proper field drainage, will make field conditions less suitable for slugs. A perimeter of three meters around the field can be kept free of slugs by harrowing with disks every week and after each rainfall to keep the soil loose and free of weeds.

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada* for pesticides registered for slug control.

Issues for slugs

1. There is a need for the registration of additional control products for slugs.
2. There is a need for the development of new control strategies for slugs.

Weeds

Key Issues

- There is a need for the registration of new products for the control of annual and perennial weeds in brassica crops.

Table 10. Occurrence of weeds in broccoli and cabbage crops in Canada[1,2]

Weed	Cabbage			Broccoli	
	British Columbia	Ontario	Quebec	Ontario	Quebec
Annual broadleaf weeds					
Common chickweed					
Common groundsel					
Lady's thumb					
Lamb's-quarters					
Wild mustard					
Wormseed mustard					
Eastern black nightshade					
Hairy nightshade					
Redroot pigweed					
Purslane					
Common ragweed					
Wild buckwheat					
Hairy galinsoga					
Shepherd's-purse					
Grasses					
Barnyard grass					
Crabgrass					
Foxtail					
Quackgrass					
Perennial weeds					
Field horsetail					
Yellow nutsedge					
Dandelion					

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest not present.

Data not reported.

[1]Source: Brassica crop stakeholders in reporting provinces. The data reflect the 2015, 2014 and 2013 production years.

[2]Refer to Appendix 1 for further information on colour coding of occurrence data.

Table 11. Adoption of weed management practices for broccoli and cabbage production in Canada[1]

	Practice / Pest	Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds	Cruciferous weeds
Avoidance	Planting/ harvest date adjustment					
	Crop rotation					
	Choice of planting site					
	Optimizing fertilization					
	Use of weed-free seed					
Prevention	Equipment sanitation					
	Mowing/ mulching/ flaming					
	Modification of plant density (row or plant spacing; seeding)					
	Seeding/ planting depth					
	Water/ irrigation management					
	Weed management in non-crop lands					
	Weed management in non-crop years					
	Tillage/ cultivation					
Monitoring	Scouting/ field inspection					
	Field mapping of weeds/ record of resistant weeds					
	Soil analysis					
	Use of portable electronic devices in the field to access pest identification/management information					
	Use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					

...continued

Table 11. Adoption of weed management practices for broccoli, cabbage and cauliflower production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds	Cruciferous weeds
Decision making tools	Economic threshold					
	Weather/ weather-based forecast/ predictive model					
	Recommendation from crop specialist					
	First appearance of weed or weed growth stage					
	Observed crop damage					
	Crop stage					
Suppression	Pesticide rotation for resistance management					
	Soil amendments					
	Biopesticides					
	Release of arthropod biological control agents					
	Habitat/ environment management					
	Ground cover/ physical barriers					
	Mechanical weed control					
	Targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					
Crop specific practices	Manual weeding					

This practice is used to manage this pest by at least some growers.

This practice is not used by growers to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1] Source: Brassica vegetable (cabbage and broccoli) stakeholders in reporting provinces (Ontario and Quebec). The data reflect the 2015, 2014 and 2013 production years.

Table 12. Herbicides and bioherbicides registered for the control of weeds in brassica vegetable production in Canada

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
carfentrazone-ethyl (hooded sprayer applications)	CG5: Brassica (cole) leafy vegetables	triazolinone	inhibition of protoporphyrinogen oxidase (Protox, PPO)	14	R	annual broadleaf weeds; actively growing broadleaf weeds up to 10 cm tall
chlorthal-dimethyl (DCPA)	broccoli, Brussels sprouts, cabbage, cauliflower	benzoic acid	microtubule assembly inhibition	3	RES	crabgrass, annual grasses, certain broadleaf weeds
clopyralid	broccoli, cabbage, cauliflower (transplanted)	pyridine carboxylic acid	synthetic auxin	4	R	ragweed, vetch, common groundsel, Canada thistle, and sheep sorrel (suppression)
diquat (stale seedbed, inter-row directed chemical weeding)	cole crops	bipyridylium	photosystem-I-electron diversion	22	R	broadleaf weeds
fenoxaprop-p-ethyl (eastern Canada and British Columbia only)	broccoli, cabbage, cauliflower	aryloxyphenoxy-propionate 'FOP'	inhibition of acetyl CoA carboxylase (ACCase)	1	R	foxtail (green and yellow), barnyard grass, crabgrass, wild proso millet, fall panicum, old witch grass, volunteer corn
fluazifop-p-butyl	broccoli, Brussels sprouts, cabbage, cauliflower	aryloxyphenoxy-propionate 'FOP'	inhibition of acetyl CoA carboxylase (ACCase)	1	R	grass weeds
flumioxazin	broccoli (transplanted)	N-phenylphthalimide	inhibition of protoporphyrinogen oxidase (Protox, PPO)	14	R	annual broadleaf weeds, dandelion, green foxtail (suppression)

...continued

Table 12. Herbicides and bioherbicides registered for the control of weeds in brassica vegetable production in Canada

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
glyphosate (present as isopropylamine salt)	(all crops, pre-plant treatment)	glycine	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	9	R	annual and perennial weeds
metam-sodium	ornamentals, food and fibre crops, tobacco	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[3]	8F[5]	RE	germinating weed seeds, suppression of perennial weeds, symphylans (garden centipede), soil-borne fungal diseases (rhixoctonia, pythium, fusarium, phytophthora, verticillium, sclerotinia,oak root fungus, clubroot and nematodes)
napropamide	broccoli, cabbage, cauliflower; Brussels sprouts in British Columbia only	acetamide	inhibition of mitosis	15	R	grasses and broadleaf weeds
oxyfluorfen	broccoli, cabbage, cauliflower	diphenylether	inhibition of protoporphyrinogen oxidase (Protox, PPO)	14	R	redroot pigweed, common purslane, suppression of lady's thumb and eastern black nightshade
paraquat (stale seedbed technique, inter-row directed chemical weeding)	cole crops	bipyridylium	photosystem-I-electron diversion	22	R	grasses and broadleaf weeds
s-metolachlor and R-enantiomer	broccoli, cabbage, cauliflower (transplanted)	chloroacetamide	inhibition of mitosis	15	RE	American nightshade, eastern black nightshade, crabgrass (smooth, hairy), barnyard grass, redroot pigweed (suppression), fall panicum, foxtail (green, yellow, giant), old witchgrass, yellow nutsedge

...continued

Table 12. Herbicides and bioherbicides registered for the control of weeds in brassica vegetable production in Canada

Active Ingredient[1]	Specific Crop or Group (CG) of Registration[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
sethoxydim	broccoli, Brussels sprouts cabbage, cauliflower	cyclohexanedione 'DIM'	inhibition of acetyl CoA carboxylase (ACCase)	1	R	annual grasses, wild oats, volunteer cereals, quackgrass
sulfentrazone	Crop subgroup 5-13 (5A): Head and stem Brassica (transplants only)	triazolinone	inhibition of protoporphyrinogen oxidase (Protox, PPO)	14	R	wild buckwheat, kochia, lamb's-quarters, redroot pigweed, cleavers, Powell pigweed, Eastern black nightshade, common waterhemp, smooth crabgrass, large crabgrass, yellow woodsorrel, common groundsel and common purslane
trifluralin (eastern Canada and British Columbia only	broccoli, Brussels sprouts, cabbage, cauliflower)	dinitroaniline	microtubule assembly inhibition	3	R	most annual grasses and many broadleaf weeds

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). **The list includes all active ingredients registered as of February 15, 2018.** The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Crop groups as described in *Residue Chemistry Crop Groups* https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/protecting-your-health-environment/pesticides-food/residue-chemistry-crop-groups.html (accessed February 27, 2018).

[3]Source: Weed Science Society of America (WSSA). Herbicide Mechanism of Action (MOA) Classification list (last modified August 16, 2017) http://wssa.net (accessed February 19, 2018)

[4]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2017-18, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2017-2022*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[5]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.3; July 2017)* (www.irac-online.org) (accessed February 19, 2018).

Annual and perennial weeds

Pest information

Damage: Weeds compete with the crop for light, water and nutrients. If not controlled they will reduce crop growth and yield. Cruciferous weeds may also harbour diseases and pests which can spread into the crop.

Life cycle: Annual weeds complete their life cycle in one year, going from seed germination through vegetative growth to new seed production. Annual weeds reproduce and spread through the production of large numbers of seeds. Most arable land is infested with annual weed seeds at all times. Some weed seeds can remain viable in the soil for many years, germinating when conditions are suitable. Perennials weeds live for many years. They can reproduce and spread by seed, and also vegetatively through expansion of their root systems. Tillage practices can break up root systems and contribute to the spread of perennial weeds.

Pest management

Cultural controls: Crop rotation is essential, allowing for the control of weeds in non-brassica crop years. It is important to select planting sites that are free from significant weed infestations. Shallow cultivation can be used as a mechanical means of destroying weeds. Early control of weeds allows brassica crops to successfully out-compete weeds that emerge later. A good fertility program will help maintain the crop's competitive advantage. The use of transplants makes weed control much easier, as the crop is given a head start over the weeds. Transplants are also more tolerant of herbicide applications than emerging seedlings and produce more uniform stands. Brassica crops are sensitive to some herbicide residues so it is important to review the herbicide use history of fields prior to planting. Additional management practices for weeds are listed in *Table 11. Adoption of weed management practices for broccoli and cabbage production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 12. Herbicides and bioherbicides registered for the control of weeds in brassica vegetable production in Canada for herbicides* registered for weed control in brassica crops.

Issues for weeds

1. There is a need to register new products for the control of annual and perennial weeds in brassica crops.

Resources

Integrated pest management / integrated crop management resources for production of brassica crops in Canada

Agri-Reseau. http://www.agrireseau.qc.ca (*site in French only*)

British Columbia Ministry of Agriculture – Plant Health.
https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/plant-health?keyword=Integrated&keyword=pest&keyword=managment

British Columbia Ministry of Agriculture – Vegetable Production Guide –Cole Crops.
http://productionguide.agrifoodbc.ca/guides/17

Centre de référence en agriculture et agroalimentaire du Québec. http://www.craaq.qc.ca

Government of Canada. Pesticides and Pest Management.
https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html

Howard, J.R., Garland J.A. and Seaman W.J. Eds. 1994. *Disease and Pests of Vegetable Crops in Canada.* 554 pp. Canadian Phytopathological Society and Entomological Society of Canada.
https://phytopath.ca/publication/books/

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). Crop Publications.
http://www.omafra.gov.on.ca/english/crops/publications.html

Ontario Ministry of Agriculture, Food and Rural Affairs. *Ontario Crop IPM: Brassica.*
http://www.omafra.gov.on.ca/IPM/english/index.html

Ontario Ministry of Agriculture, Food and Rural Affairs. Ontario Vegetable Crop Protection Guide (2014-15) Publication 838^{E}; 2016 Supplement (838S).
http://www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. *Ontario Vegetable Production Recommendations (2010-11) OMAF Publication 363.* http://www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 75, Guide to Weed Control 2016-2017. http://www.omafra.gov.on.ca/english/crops/pub75/pub75toc.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 701, *Integrated Pest Management for Crucifers (2008)* OMAFRA Order # 701, Agdex #252 http://www.omafra.gov.on.ca/english/crops/pub701/p701order.htm

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture and Lands www.gov.bc.ca/agri	Susan Smith susan.l.smith@gov.bc.ca	Caroline Bédard caroline.bedard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture and Food www.omafra.gov.on.ca/english/	Travis Cranmer travis.cranmer@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Quebec	Ministére d'Agriculture, Pêcheries et Alimentation du Québec www.mapaq.gouv.qc.ca	Mélissa Gagnon melissa.gagnon@mapaq.gouv.qc.ca	Mathieu Côté mathieu.cote@mapaq.gouv.qc.ca

National and Provincial Vegetable Grower Organizations

British Columbia BCfresh http://bcfresh.ca/associations

Ontario Fruit and Vegetable Growers Association http://www.ofvga.org

Canadian Horticultural Council http://www.hortcouncil.ca

Appendix 1

Definition of terms and colour coding for pest occurrence table of the crop profiles.

Information on the occurrence of disease, insect and mite and weed pests in each province is provided in Tables 4, 7 and 10 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and pressure in each province as presented in the following chart.

Presence	Occurrence information				Colour Code
		Frequency	**Distribution**	**Pressure**	
Present	Data available	**Yearly** - Pest is present 2 or more years out of 3 in a given region of the province.	**Widespread** - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.	**High** - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.	Red
				Moderate - If present, potential for spread and crop loss is moderate; pest situation must be monitored and controls may be implemented.	Orange
				Low - If present, the pest causes low or negligible crop damage and controls need not be implemented.	Yellow
			Localized - The pest is established as localized populations and is found only in scattered or limited areas of the province.	**High** - see above	Orange
				Moderate - see above	White
				Low - see above	White
		Sporadic - Pest is present 1 year out of 3 in a given region of the province.	**Widespread** - as above	**High** - see above	Orange
				Moderate - see above	Yellow
				Low - see above	White
			Localized - as above	**High** - see above	Yellow
				Moderate -see above	White
				Low - see above	White
	Data **not** available	**Not of concern:** The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.			White
		Is of concern: The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.			Blue
Not present	The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.				Black
Data not reported	Information on the pest in this province is unknown. No data is being reported for this pest.				Grey

References

Agriculture and Agri-Food Canada. Statistical Overview of the Canadian Vegetable Industry, 2015. AAFC No. 12162E-PDF. *http://www.agr.gc.ca/eng/industry-markets-and-trade/market-information-by-sector/horticulture/horticulture-sector-reports/statistical-overview-of-the-canadian-vegetable-industry-2015/?id=1478646189894*

Brassica oleracea (cabbage, Brussels sprouts, broccoli, kohlrabi, cauliflower, kale). Biodiversity explorer. http://www.biodiversityexplorer.org/plants/brassicaceae/brassica_oleracea.htm (accessed 2014-02-12).

British Columbia Ministry of Agriculture – Plant Health. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/plant-health?keyword=Integrated&keyword=pest&keyword=managment

Government of Canada. Pesticides and Pest Management. https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html

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Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). Crop Publications. http://www.omafra.gov.on.ca/english/crops/publications.html

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). Vegetables – Brassicas: Broccoli, Cabbage, Cauliflower, Horseradish, Kale, Kohlrabi, Radish, Rutabaga, Specialty Crucifers. http://www.omafra.gov.on.ca/english/crops/hort/cole_crops.html

Ontario Ministry of Agriculture, Food and Rural Affairs. *Ontario Crop IPM: Brassica.* http://www.omafra.gov.on.ca/IPM/english/brassicas/index.html

Statistics Canada. CANSIM database. http://www5.statcan.gc.ca/cansim/home-accueil?lang=eng